Energy Scale References

D0 Escale references:

•Nim article (hep-ex/9805009)
•Other D0 talks/notes: www-d0.fnal.gov/daniel/jesgroup/jesgroup.html

Other sources of interest:
•CDF Z->B-BBAR (Jets + tracks)
  •http://home.fnal.gov/~dorigo/thesis.ps
  •http://home.fnal.gov/~dorigo/jet_corr.ps
•ALEPH Energy Flow NIM A 360 (1995) 481

Q1: What's a Jet?

all jet analyses must begin with this question

After defining the jets (choosing algorithm) the scale may be choosen

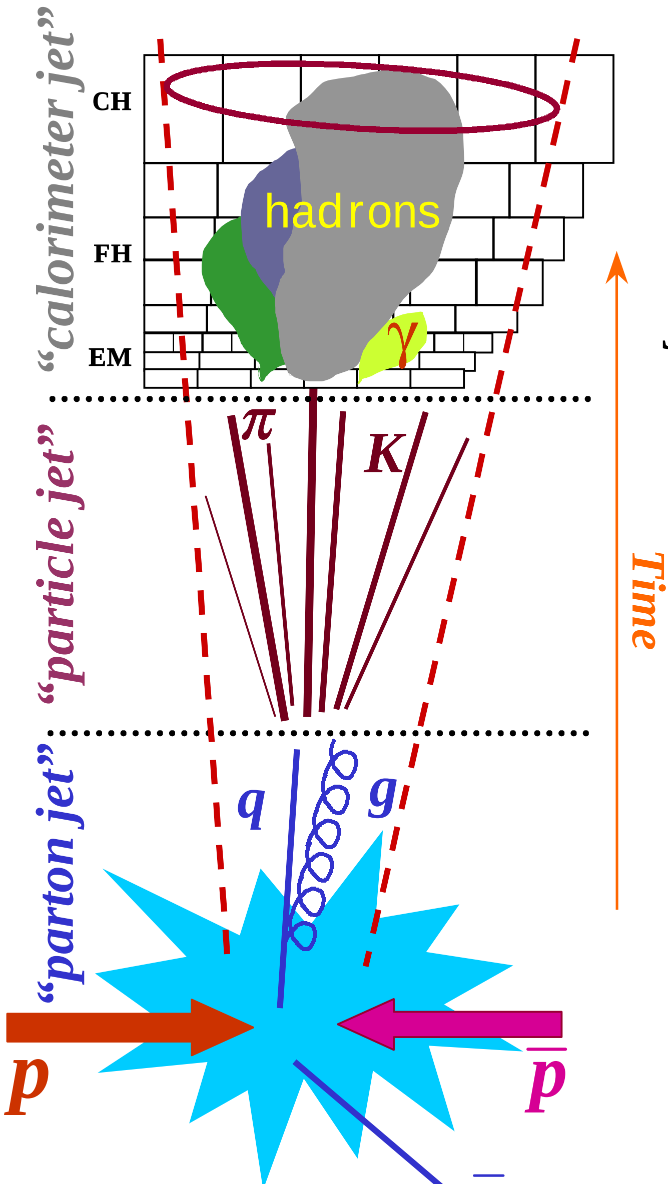
Energy Scale

A: Equivalence of particle Energy to Detector Energy

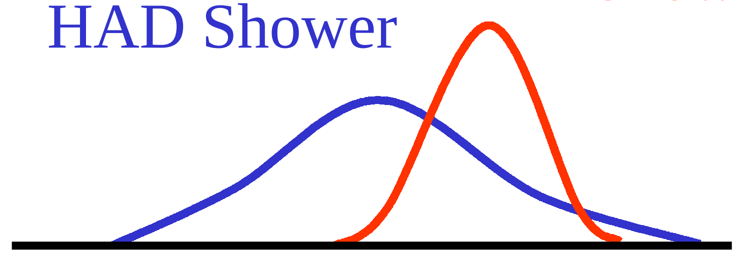
Momentum Scale

B: Equivalence of particle Momentum to Detector Momentum

Leakage?

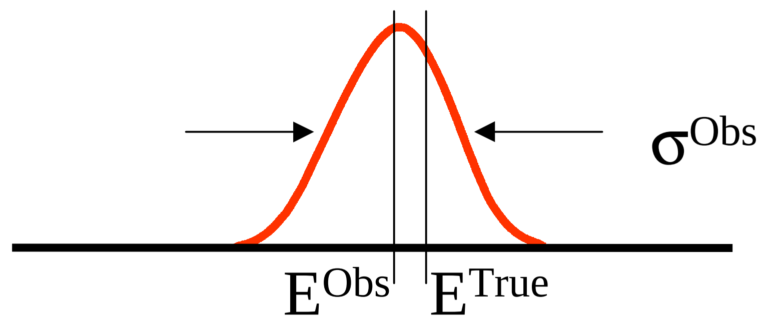


Single Particle Response

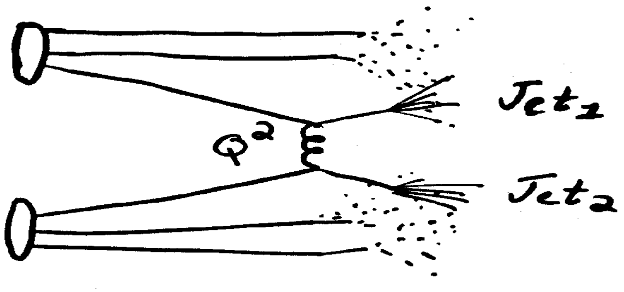


Jets are ~ <1/3> EM-like, increasing with ln(E)

Jet response in hermetic detector
CLT at work…



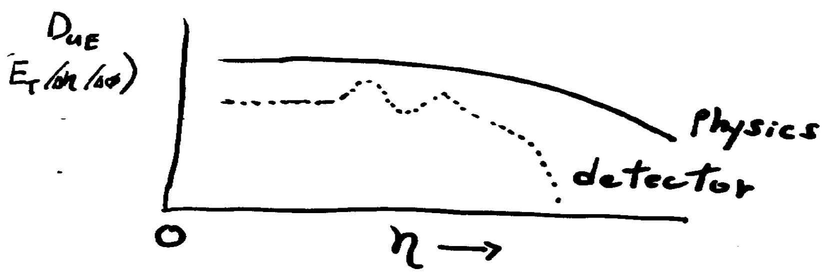
Jet scale moves $\langle E^{obs}\rangle$ to $\langle E^{obs}\rangle$
And ideally reduces overall σ



Proton remnant
Spectators
or
Underlying Event
(ULE)

Back to Q1: What's (in) a Jet?

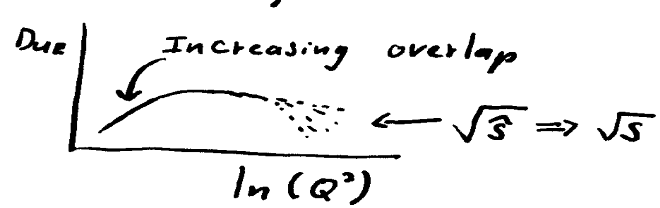
Run I choice (ULE) is not part of jet, subtract on average based on jet algorithm & η.



Density of ULE
(Min Bias Model)
$\langle E_T \rangle / \Delta\eta / \Delta\phi$

Alternate choices:

- Include ULE in jet energy
- Define ULE (Q^2)



For some recent studies of ULE in various MC and data samples see:
Fermilab-Pub-00/297
contrib. of
Field&Stuart

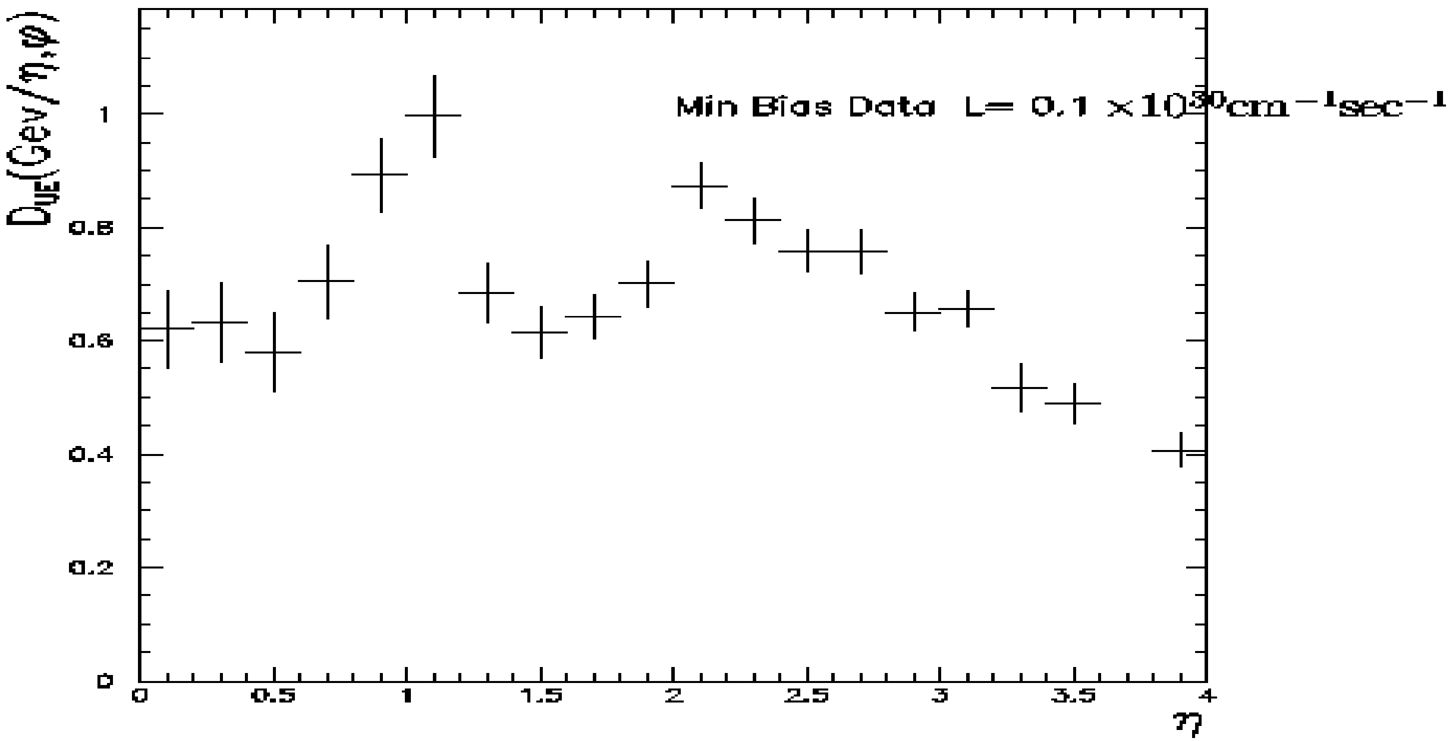
Offset Correction

$$E_T^O = E_T^{ue} + E_T^{\Theta}$$

$$E_T^O = E_T^{ue} + <N_{extra}> E_T^{ue} + E_T^{noise} + E_T^{pile}$$

E_T^{ue} underlying event from spectator interactions associated with the hard collision that caused the trigger

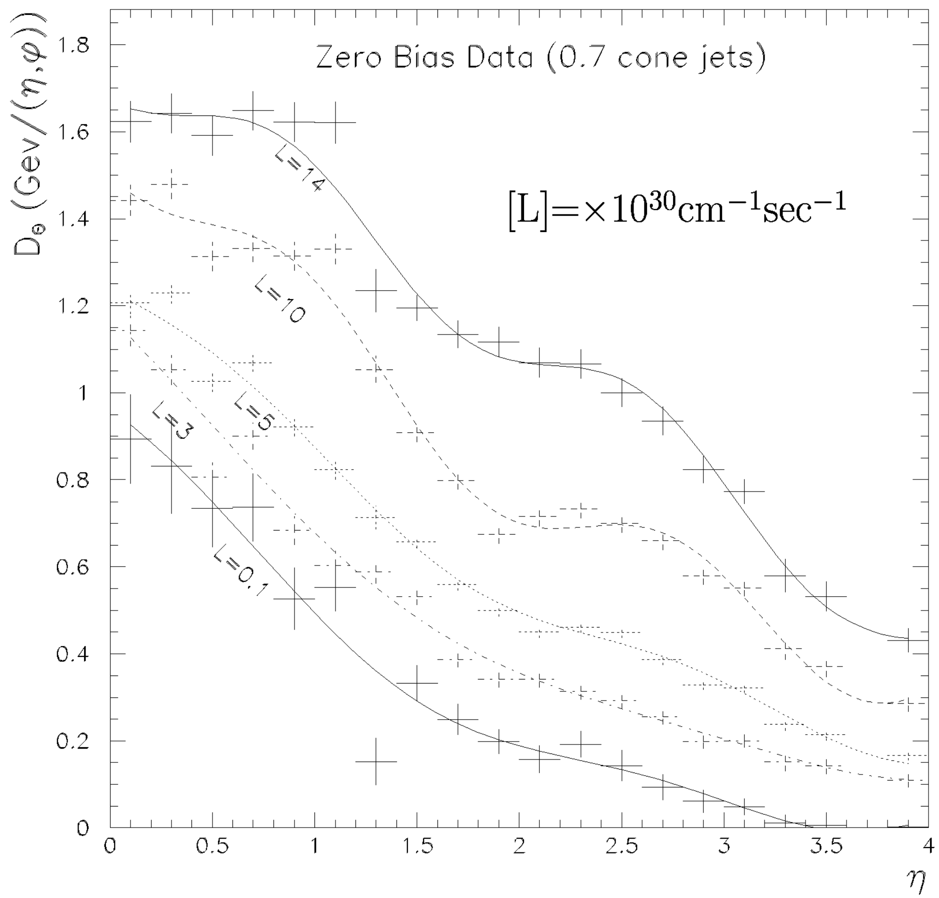
E_T^{Θ} Ur noise, pile-up and extra $p\bar{p}$ interactions



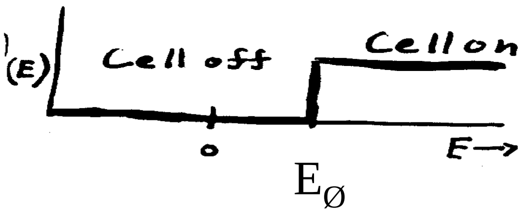
Use low luminosity MIN BIAS and ZB (no Hard Collison) data: $D_{ue}(\eta) = D_{MB}(\eta) - D_{ZB}^{no\ HC}(\eta)$

Noise, pile-up and extra $p\bar{p}$ contributions from ZB data in different luminosity bins:

$$D_\Theta(L,\eta) = D_{ZB}(L,\eta)$$



Subtraction of ULE (+noise & pileup)
Complicated by zero suppression effects



Cell readout is Zero suppressed

$$\sum_{\text{Cells}} E_{jet}\,\Theta(E_{jet}, E_\varnothing) + E_{noise}\,\Theta(E_{noise}, E_\varnothing) + E_{ULE}\,\Theta(E_{ULE}, E_\varnothing)$$

$$\neq \sum_{\text{Cells}} E_{Total}\,\Theta(E_{Total}, E_\varnothing)$$

E_{jet} is not a simple 1 offset component subtraction

$$E_{jet} = E_{Total} - \langle E^{ULE} \rangle - \langle E^{noise} \rangle - O_c(E, \eta, L)$$

The offset correction depends on occupancy.

Run 1 (cone): develop emperical occupancy correct from data to get back E_{jet}

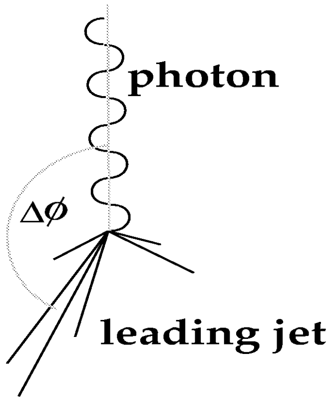
Run 1 (k_T): Overlay noise + ULE + generated jets apply ZSP in software & directly measure effect on jets

Response Correction

Jet Respone is typically < 1.

- $h/e \neq 1$
- **Uninstrumented regions**
- **Module to module fluctuations**

Missing E_T Projection Fraction Method



Based on event energy balance in the transverse plane

In an ideal calorimeter:

$$\vec{E}_{T\gamma} + \vec{E}_T^{had} = 0$$

In the DØ calorimeter:

$$R_{em}\vec{E}_{T\gamma} + R_{had}\vec{E}_T^{had} = -\vec{\not{E}}_T$$

Once photons are calibrated, $R_{em} = 1$: $R_{had} = 1 + \frac{\vec{\not{E}}_T \cdot \hat{n}_{T\gamma}}{E_{T\gamma}}$

For a γ-jet two body process: $R_{jet} = R_{had}$

To avoid resolution bias and effect of a steeply falling γ cross section:

R_{jet} versus E'	**with**	$E' = E_{T\gamma}\cosh(\eta_{jet})$
$E' \rightarrow E_{jet}^{meas}$	**and**	R_{jet} versus E_{jet}^{meas}

($E_{T\gamma}$ and η_{jet} measured with good resolution)

Cryostat Factor Correction

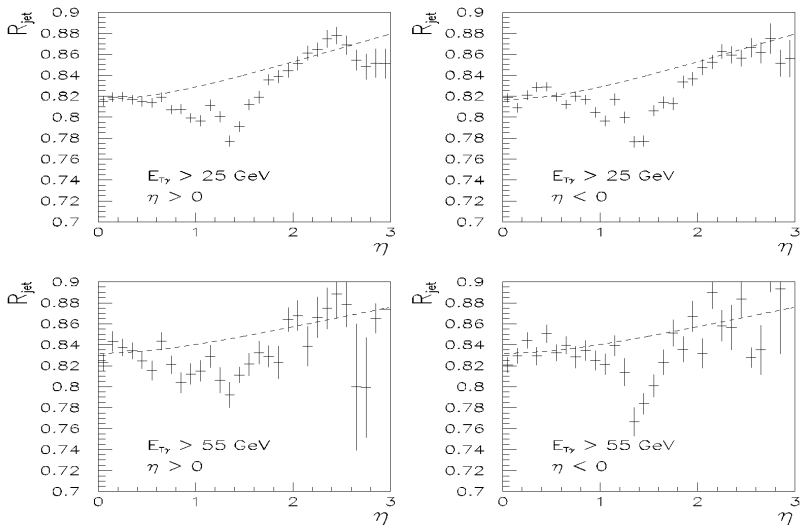
F_{cry}: **Ratio of** R_{jet}^{EC} **over** R_{jet}^{CC}

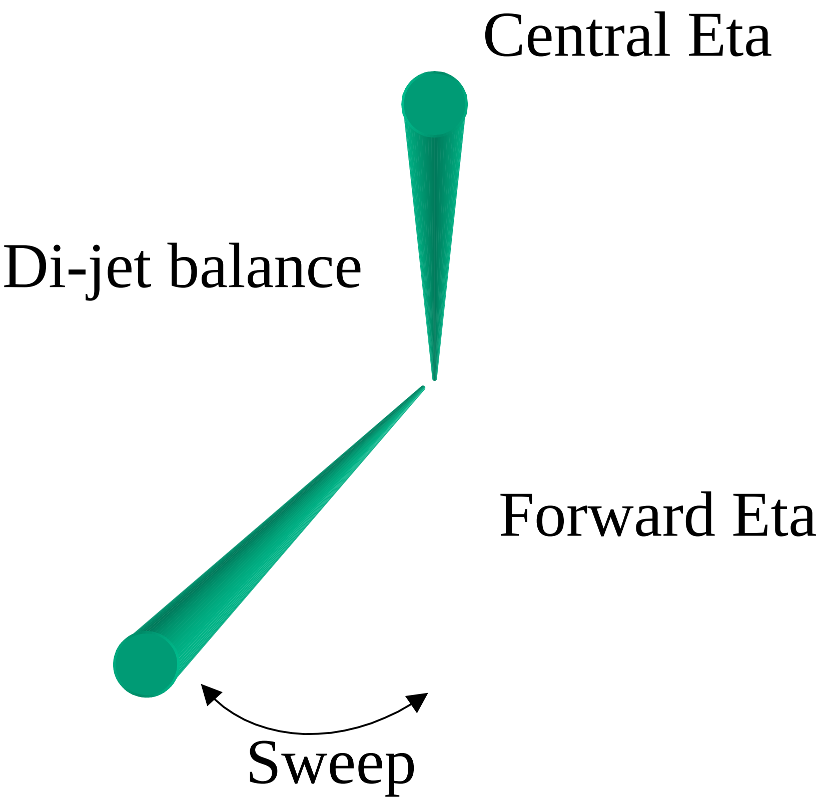
SAME TECHNOLOGY $\Rightarrow F_{cry}$ **flat as a function of** E'

- **Calibrate EC with respect to CC**
- **Use EC points to extend the energy reach of CC measurement**

=*Detector uniformity corrections*

η Dependent Correction, F_η





$R_{jet} = \alpha + \beta \cdot \ln(E) \Rightarrow R_{jet} = a + b \cdot \ln[\cosh(\eta)]$

F_η **correction defined as the difference between**

EXPECTED R_{jet} **and MEASURED** R_{jet} **in the IC**

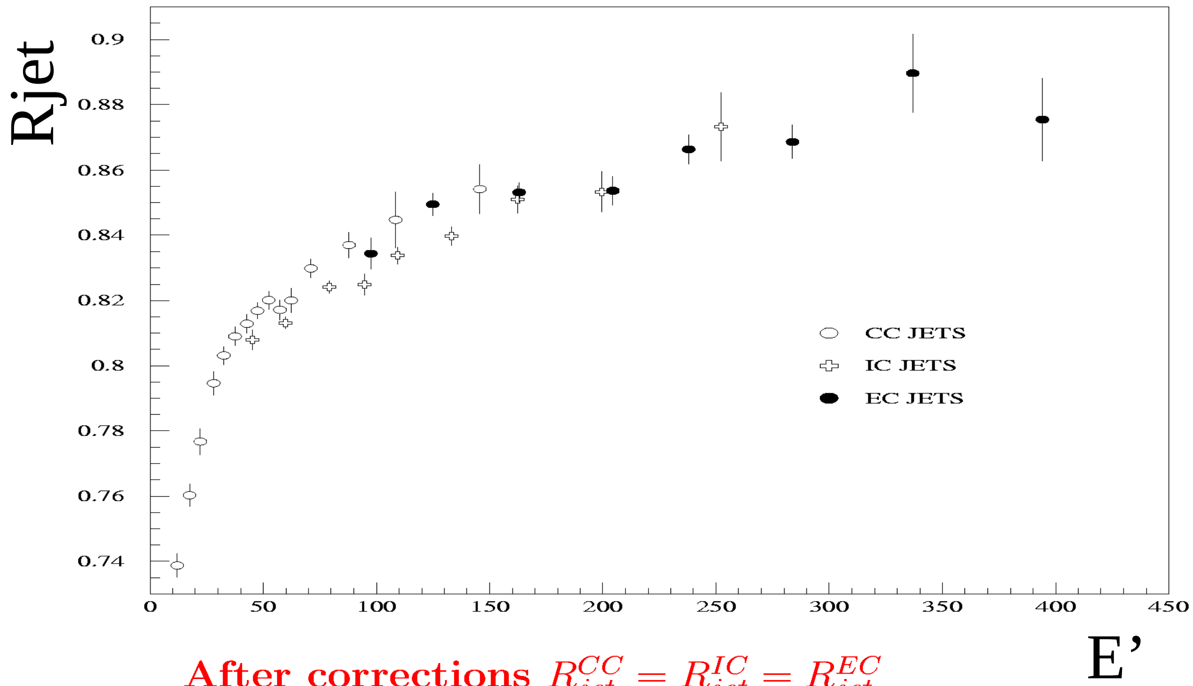
CC Response Measurement

F_{cry} **and** F_η **make the Calorimeters "UNIFORM":**

- **Apply offset correction to** E_{Tjet}^{meas} **(**$\vec{\not{E}}_T$ **STAYS THE SAME)**
- **Apply** F_{cry} **and** F_η **to** E_{Tjet}^{meas} **and** $\vec{\not{E}}_T$

$$E_{Tjet}^{corr} = E_{Tjet}^{meas} \times F_{cry} \times F_\eta$$

$$\vec{\not{E}}_T{}^{corr} = \vec{\not{E}}_T{}^{meas} + \sum_\gamma \vec{E}_{T\gamma}^{meas} - \sum_\gamma \vec{E}_{T\gamma}^{corr} + \sum_{jet} \vec{E}_{Tjet}^{meas} - \sum_{jet} \vec{E}_{Tjet}^{corr}$$

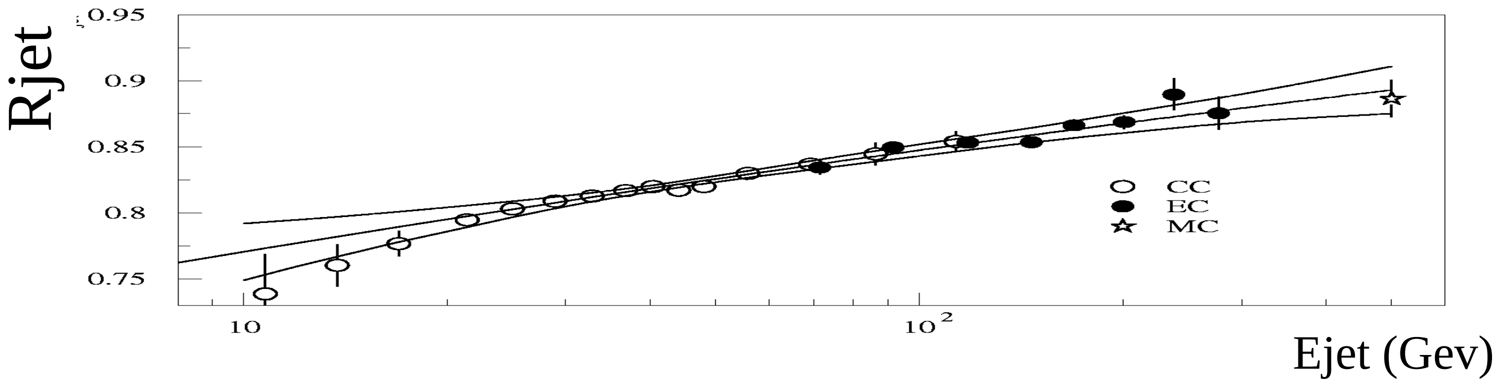


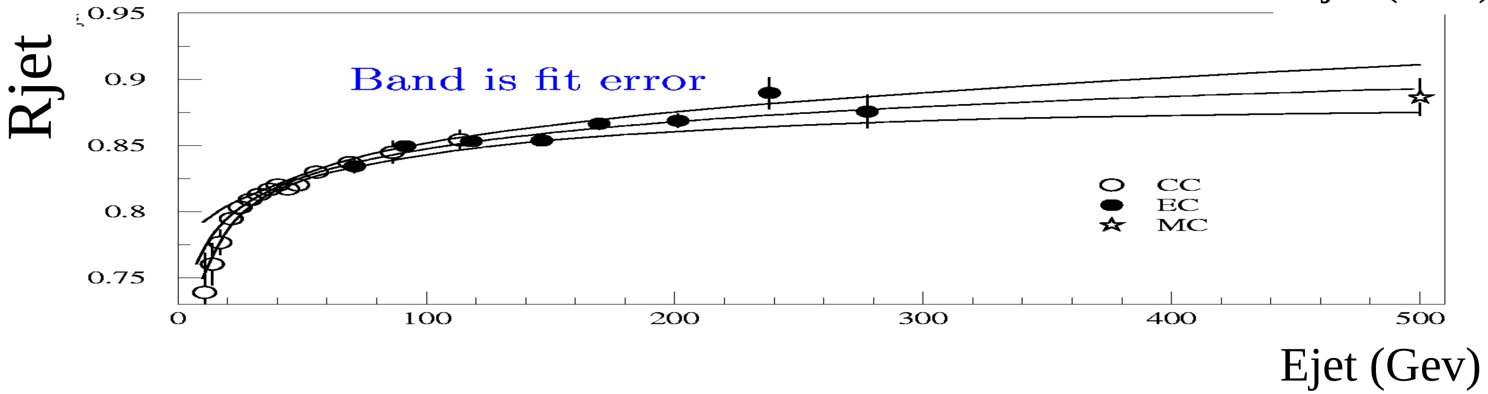
After corrections $R_{jet}^{CC} = R_{jet}^{IC} = R_{jet}^{EC}$
(to within $\sim$ **1%)**

R_{jet} versus E_{jet}

If $h/e \neq 1 \Rightarrow \pi/e \sim 0.1 \times \ln(E(GeV))$

$$R_{jet} = A + B \cdot \ln(E_{jet}) + C \cdot [\ln(E_{jet})]^2$$





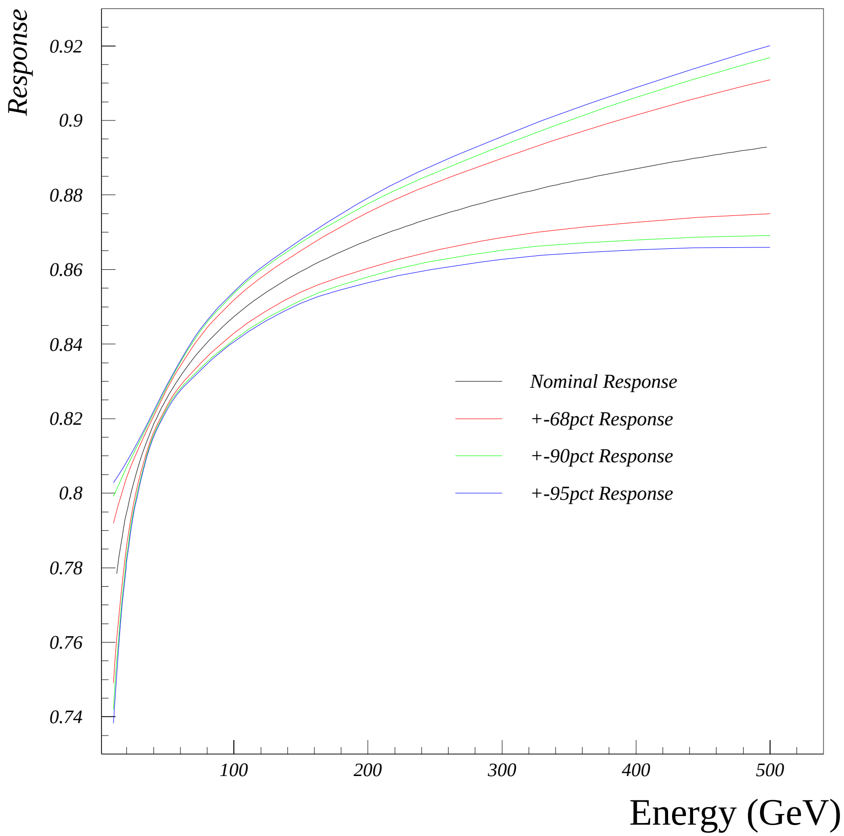
CC, EC points used below 300 GeV

MC point (hybrid data set) from convolution of HERWIG jet events and Test Beam single particle response:

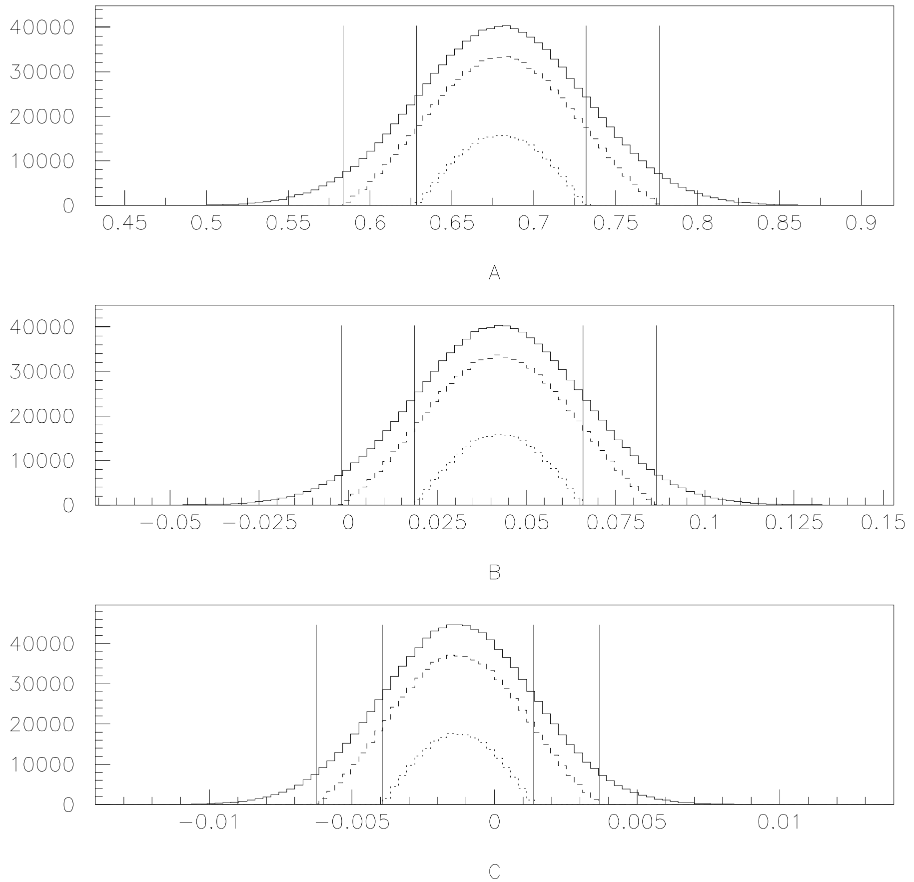
Shape of R_{jet}^{data} and R_{jet}^{hyb} agree at high $E_{jet} \Rightarrow$ use MC point to constrain the fit

A more detailed look at Response

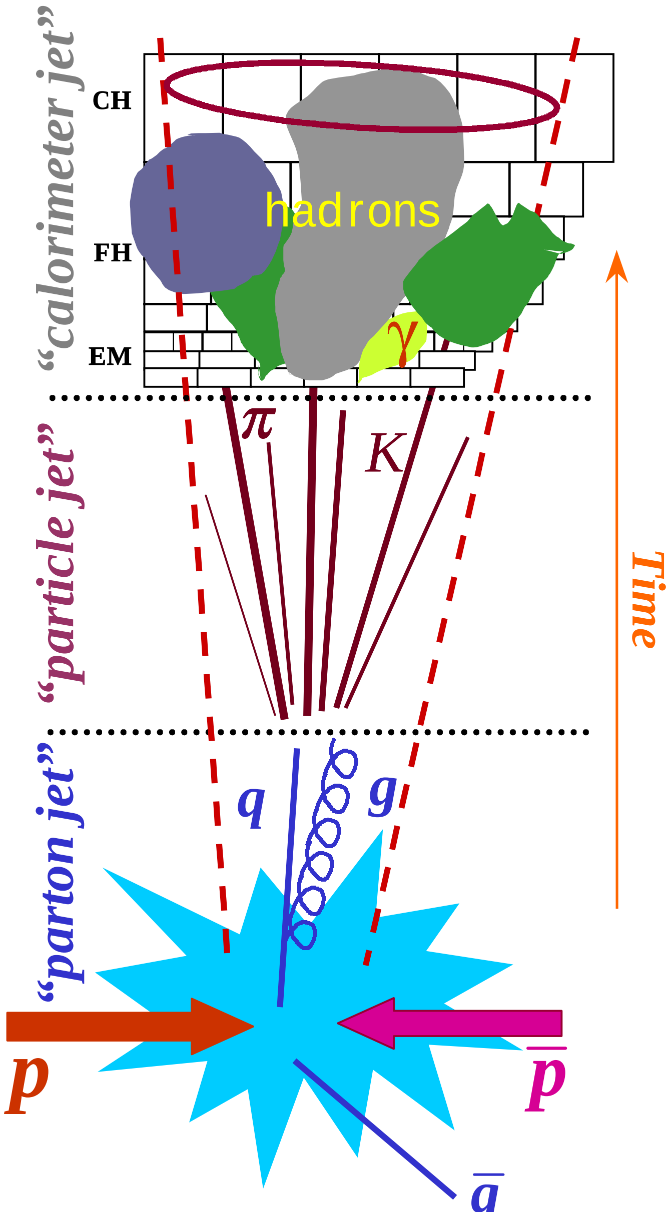
Sample probability distribution for fit parameters:
This distribution contains information for allowed response shapes and their relative likelihoods



Outer bands - 68% CL, all params. free
Inner bands - 68% CL, 1 param. free

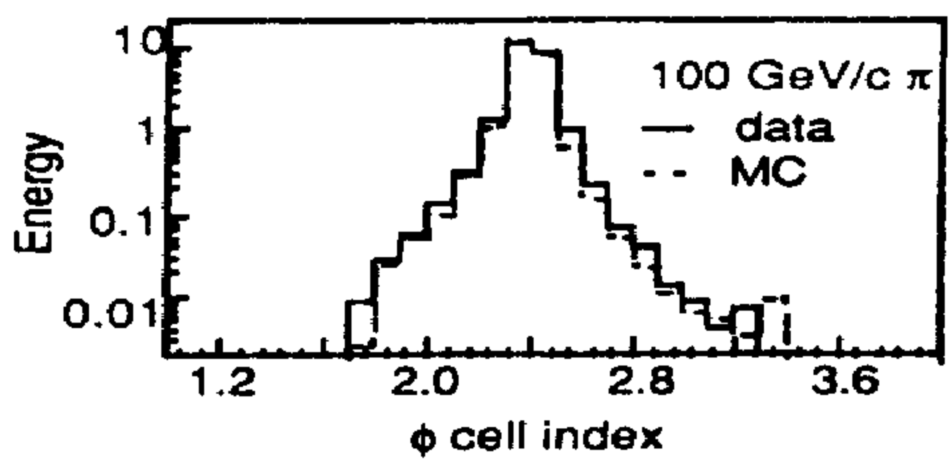


Showering



Particles emitted inside cone, but depositing energy out of cone in detector

Opposite effect can also occur leading to energy showering into cone



Transverse shower shape, 100 GeV pions

Showering

Method:

- Test your MC against jet and single particle profiles
- (un)Correct particle-level jets for detector response to get the detector energy associated w/the particle jets
- Compare fraction of this detector energy that lies w/in the jet cone (in the detector) to total detector energy

This compensates for energy showered into/out of the cone.

But… MPF method bias effects can cause double correction

$$R_{had} \equiv 1 + MPF = 1 + \frac{\vec{\not{E}}_T \cdot \hat{n}_T^{\gamma}}{E_T^{\gamma}}$$

Missing E_T in direction of photon can be biased by widely showering jets

Solution involves some ‘tuning’ of limits for following particle showers

Some words about RunII

New opportunities w/ E/P measurement from tracker may be helpful for lower PT jets – MPF method still superior for high PT

Determine offset corrections from MB data + MC jets

Revisit solutions for MPF bias in showering correction

Separate b-jet scales (Z->b-bbar, gamma+bjet)

Work underway on EFLOW type corrections